

AperTO - Archivio Istituzionale Open Access dell'Università di Torino

**Chalcid parasitoid community associated with the invading pest *Dryocosmus kuriphilus* in north-western Italy**

**This is the author's manuscript**

*Original Citation:*

*Availability:*

This version is available <http://hdl.handle.net/2318/131889> since 2016-10-12T09:53:33Z

*Published version:*

DOI:10.1111/j.1752-4598.2012.00192.x

*Terms of use:*

Open Access

Anyone can freely access the full text of works made available as "Open Access". Works made available under a Creative Commons license can be used according to the terms and conditions of said license. Use of all other works requires consent of the right holder (author or publisher) if not exempted from copyright protection by the applicable law.

(Article begins on next page)



UNIVERSITÀ DEGLI STUDI DI TORINO

This is an author version of the contribution published on:

A. Quacchia, C. Ferracini, J.A. Nicholls, E. Piazza, M.A. Saladini, F. Tota, G.  
Melika, A. Alma

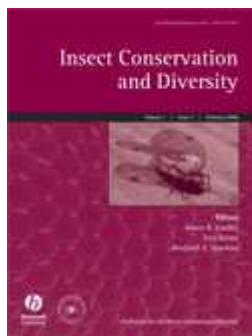
Chalcid parasitoid community associated with the invading pest *Dryocosmus*  
*kuriphilus* in north-western Italy

INSECT CONSERVATION AND DIVERSITY (2013) 6

DOI: 10.1111/j.1752-4598.2012.00192.x

The definitive version is available at:

<http://doi.wiley.com/10.1111/j.1752-4598.2012.00192.x>



## Chalcid parasitoid community associated with the invading pest *Dryocosmus kuriphilus* in north-western Italy

Journal:	<i>Insect Conservation and Diversity</i>
Manuscript ID:	ICDIV-11-0164.R1
Manuscript Type:	Minor Review
Date Submitted by the Author:	05-Jan-2012
Complete List of Authors:	Quacchia, Ambra; University of Torino, DIVAPRA Ferracini, Chiara; University of Torino, DIVAPRA Nicholls, James; University of Edinburgh, Institute of Evolutionary Biology Piazza, Enzo; University of Torino, DIVAPRA Melika, George; Vas County Plant Protection and Soil 15 Conservation Service, Systematic Parasitoid Laboratory Alma, Alberto; University of Torino, DIVAPRA
Keywords:	<i>Dryocosmus kuriphilus</i> , Chalcidoidea, indigenous parasitoids, biodiversity, chestnut gallwasp

1  
2  
3 1 **Chalcid parasitoid community associated with the invading pest *Dryocosmus kuriphilus* in**  
4  
5  
6 2 **north-western Italy**  
7  
8 3  
9  
10 4 Running title: Native parasitoids of *Dryocosmus kuriphilus*  
11  
12  
13 5  
14  
15 6 Ambra Quacchia<sup>1</sup>, Chiara Ferracini<sup>1</sup>, James A. Nicholls<sup>2</sup>, Enzo Piazza<sup>1</sup>, Matteo Alessandro  
16  
17 7 Saladini<sup>1</sup>, Federica Tota<sup>1</sup>, George Melika<sup>3</sup>, Alberto Alma<sup>1</sup>  
18  
19  
20 8  
21  
22 9 <sup>1</sup>DIVAPRA-Entomologia e Zoologia applicate all’Ambiente ‘Carlo Vidano’, University of Turin,  
23  
24 10 Grugliasco (TO), Italy  
25  
26  
27 11 <sup>2</sup>Institute of Evolutionary Biology, University of Edinburgh, Edinburgh, UK  
28  
29 12 <sup>3</sup>Pest Diagnostic Laboratory, Vas County Plant Protection and Soil Conservation Directorate,  
30  
31 13 Tanakajd, Hungary  
32  
33  
34 14  
35  
36 15 Correspondence: Ambra Quacchia, DIVAPRA-Entomologia e Zoologia applicate all’Ambiente  
37  
38 16 ‘Carlo Vidano’, University of Turin, via Leonardo da Vinci 44, 10095, Grugliasco (TO), Italy.  
39  
40  
41 17 Phone number: 00390116708677, Fax: 00390116708535, E-mail: ambra.quacchia@unito.it  
42  
43  
44 18  
45  
46 19  
47  
48 20  
49  
50  
51 21  
52  
53 22  
54  
55 23  
56  
57  
58 24  
59  
60 25  
  
26

## Abstract

1. Biological invasions of exotic species pose a major threat to native biodiversity. Invaders are known to have direct impacts on native species; however, less well studied are the indirect impacts mediated through the integration of invaders into trophically-linked communities.

2. A survey of the chalcid wasp parasitoid community attacking the chestnut gallwasp *Dryocosmus kuriphilus* was carried out over a five year period at 26 sites in north-western Italy. More than 415,000 galls were collected and more than 10,000 parasitoid specimens emerged. Twenty-seven parasitoid species belonging to six families (Eurytomidae, Pteromalidae, Torymidae, Eupelmidae, Ormyridae, Eulophidae) were identified using morphological and molecular methods; seventeen are new records for the parasitoid community associated with *D. kuriphilus* in Italy. The morpho-species complexes *Megastigmus dorsalis*, *Eupelmus urozonus*, *E. annulatus* and *Eurytoma pistaciae* were the dominant species, another six morpho-species were encountered regularly but at low frequency, and 13 species were recorded only occasionally. The attack rate of any individual parasitoid species was low, although the more common species appeared to be increasing their use of this novel host.

3. Biases observed in the sex ratios of parasitoids emerging from *D. kuriphilus* galls suggest that parasitoid individuals are making life history decisions to take advantage of the high abundance of this host. Overall, these patterns imply that there is ongoing transfer of parasitoids between oak and chestnut galls, and hence a high potential for this invading species to have a major impact on native oak gall communities via indirect competition mediated through shared parasitoids.

## Keywords

*Dryocosmus kuriphilus*, Chalcidoidea, indigenous parasitoids, biodiversity, chestnut gallwasp

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60  
61  
62  
63  
64  
65  
66  
67  
68  
69  
70  
71  
72  
73  
74  
75  
76

**Introduction**

The introduction of exotic species is occurring more and more frequently around the world, especially in countries with extensive international exchange of goods and tourists, and poses a widely recognized threat to native biodiversity (Williamson, 1996; Wittenberg & Cock, 2001). Understanding the causes and consequences of biological invasions subsequent to such introductions represents an increasingly important challenge for ecologists and evolutionary biologists. Many invasive species undergo population explosions and spread rapidly since they are released from their normal controls of disease and natural enemies (van Lenteren *et al.*, 2006). The resulting ecological impact of invaders can occur at different levels of biological organisation from genetic effects through effects on individuals, populations or communities to effects on ecosystem processes (Parker *et al.*, 1999). Expanding populations of exotic species can disrupt ecosystems directly through displacement and extinction of native species (Wilson, 1997), causing both economic and environmental damage. Invasive herbivores may affect populations and communities of native herbivores by competing for the same resource, although mechanisms underlying competition are not always fully understood (Reitz & Trumble, 2002). However, when trophic links are established between invasive species and native communities, invaders can impact indirectly on these communities through perturbed trophic structures (Vitousek *et al.*, 1996; Hennemann & Memmot, 2001). Hence understanding the process by which native natural enemies recruitment onto novel invading hosts provides insight into the broader effects of invading species.

*Dryocosmus kuriphilus* Yasumatsu (Hymenoptera, Cynipidae), native to China, is a key pest of chestnut trees (Fagaceae, *Castanea* spp.) (Payne *et al.*, 1983; Moriya *et al.*, 1990; Murakami *et al.*, 1995). This species became established in the mid 20<sup>th</sup> century in Japan, Korea and the USA. In Europe it was first reported in 2002 from Piedmont in north-west Italy (Brussino *et al.*, 2002), but from customs records its introduction can be traced back to 2–3 years beforehand with the importation of nursery material from China (Quacchia *et al.*, 2008). Due to the severe impact that the galls induced by this species have on host plant growth and nut production it was added to the

European Plant Protection Organization (EPPO) A2 Action list (EPPO, 2005) in 2003. *Dryocosmus kuriphilus* has one generation per year, with parthenogenetic females laying eggs in the buds of *Castanea* spp. during summer which then hatch in 30-40 days. First instar larvae overwinter and grow slowly until the following spring at which point their growth rate increases leading to the induction of galls inside which the gallwasp larvae develop. Native parasitoids that normally attack galls induced by related cynipid gallwasps on oaks (Fagaceae, *Quercus* spp.) have colonised *D. kuriphilus* galls everywhere throughout their introduced range (Aebi *et al.*, 2006, 2007). Given the high abundance of *D. kuriphilus* galls, the use of this species as a host by oak gall parasitoids may have massive, but to date unstudied, impacts on the oak gall community through the process of apparent competition (Holt, 1977). However, to understand the impacts of this invading species we first need to know basic information on the identity and behaviour of native parasitoids colonising it.

A total of 11 species in five chalcid families (Torymidae, Ormyridae, Eurytomidae, Eupelmidae and Eulophidae) are known to attack *D. kuriphilus* in its native range in China (Murakami *et al.*, 1980; Kamijo, 1981; Murakami, 1981; Luo & Huang, 1993). Of these, only *Torymus sinensis* Kamijo, shows high host specificity and a life cycle matching that of its host; the remaining species also attack related cynipid hosts galling oaks. In Japan introduced *D. kuriphilus* is now attacked by a rich parasitoid wasp assemblage of 24 chalcid species from seven families and one braconid species (*Aspilota yasumatsui* Watanabe) (Aebi *et al.*, 2006; Abe *et al.*, 2007). After its arrival in Korea, *D. kuriphilus* recruited a parasitoid assemblage of 17 chalcid species over a period of only several decades (Ko, 1971; Yasumatsu & Kamijo, 1979; Kamijo, 1981, 1982; Murakami *et al.*, 1985, 1994, 1995; Ôtake, 1989; Ôtake *et al.*, 1982; Kim, 1998). Preliminary surveys of the natural enemies attacking *D. kuriphilus* in Italy were published by Aebi *et al.* (2006, 2007) in which 15 species belonging to five chalcid families were identified. Although the communities associated with introduced populations of *D. kuriphilus* are richer than those found in its native Chinese range, the latter is almost certainly understudied. However, the parasitoid communities of *D. kuriphilus* in

1  
2  
3 103 both native and introduced ranges show substantial overlap in species composition and consistent  
4  
5 104 biological patterns (Aebi *et al.*, 2006). Parasitoid communities based around invading *D. kuriphilus*  
6  
7  
8 105 develop rapidly, involving species shared with local populations of oak gallwasps, typically those  
9  
10 106 with broad host ranges. The novel communities are also diverse, both taxonomically and in terms of  
11  
12  
13 107 the life histories of component species. Although the recruitment of indigenous parasitoids onto  
14  
15 108 invading populations of *D. kuriphilus* has been fast, they have not yet provided effective control of  
16  
17 109 this pest. Given the severity of the damage caused by *D. kuriphilus* and the failure of other methods  
18  
19  
20 110 of control (such as insecticides or selection of resistant cultivars), control by native parasitoids has  
21  
22 111 been augmented by the release of *T. sinensis*, initially into Japan (with rapid effective control;  
23  
24 112 Moriya *et al.*, 1990) and subsequently to both the USA (Cooper & Rieske, 2007; Rieske, 2007) and  
25  
26  
27 113 Italy (Quacchia *et al.*, 2008).

28  
29 114 Here we present a detailed report on the native natural enemies associated with *D. kuriphilus*  
30  
31  
32 115 in the north of Italy where *D. kuriphilus* was first introduced. We provide a qualitative assessment  
33  
34 116 of the species utilising *D. kuriphilus* as a host to examine how the parasitoid community has  
35  
36 117 changed over the past five years since the preliminary surveys of Aebi *et al.* (2006). We also  
37  
38  
39 118 provide quantitative data to examine the rate of parasitoid recruitment onto this novel host, and to  
40  
41 119 examine how the demographics of this novel abundant host may affect life history decisions of the  
42  
43 120 parasitoids attacking it. Finally we discuss the possible future development of the *D. kuriphilus*  
44  
45  
46 121 parasitoid community and its interaction with the parasitoid community attacking hosts on oaks.  
47

48 122 **Materials and methods**

49  
50 123 *Gall collection and rearing*

51  
52  
53 124 Parasitoids were reared from galls of *D. kuriphilus* collected during the years 2006-2010.  
54  
55 125 Galls were collected from 26 sites within Cuneo province in north-western Italy, within a zone of  
56  
57  
58 126 850 km<sup>2</sup> bounded by 44°38'52'' and 44°12'05'' N and by 7°19'19'' and 7°49'21'' E (Figure 1).  
59  
60 127 This area has extensive infestation by *D. kuriphilus* and encompasses its initial introduction site into  
128 Italy, so likely contains the most species-rich parasitoid assemblage available. Sampled chestnut



trees were located both in mixed forests and in chestnut orchards; Cuneo province has 40% of its forestry area covered by chestnut and nearly 10% by *Quercus* spp. (IPLA, 2004). Galls were randomly collected by hand from low branches and with the aid of lopping shears from the medium-high canopy. All material was stored in plastic bags, transferred to a forest nursery “Gambarello” at Chiusa Pesio within Cuneo province and separated from any non-gall plant material to avoid contamination by other insects not associated with the galls. Galls were collected twice a year: in winter withered galls formed during the previous spring were sampled, and in summer newly formed galls were collected. The dried winter galls were kept in cardboard boxes provided with extractable skylights while the fresh summer galls were isolated inside Plexiglas and net cubes (40x40x40 cm). In both cases multiple galls (up to 2,000) were kept in every container. All galls were stored outdoors at ambient conditions.

#### *Parasitoid collection and identification*

Rearing boxes were checked once per week until the emergence of the first parasitoid wasp, after which parasitoids were collected daily and their date of emergence recorded. Gall-inducing and parasitoid wasps were removed using an entomological pooter, then stored in 99% ethanol. All the parasitoids were initially identified using morphological characters. Voucher specimens of parasitoids were deposited at the University of Turin, DIVAPRA Entomology section. Some of the parasitoid taxa encountered contain morphologically-cryptic species distinguishable only through the use of molecular markers; these groups include *Megastigmus dorsalis* (Fabricius), *Eurytoma brunniventris* Ratzeburg and the *Eupelmus urozonus* Dalman/*E. annulatus* Nees complex (Karttinen *et al.*, 2010; Nicholls *et al.*, 2010). Between 7 and 43 individuals per morpho-species complex were sequenced to determine whether multiple species were present. The sample for each morpho-species was derived evenly from the winter and summer collections of their hosts. Samples were sequenced either for the cytochrome *b* gene (*Megastigmus*, *Eurytoma*) following methods in Nicholls *et al.* (2010) or the cytochrome oxidase I gene (*Eupelmus*) following Karttinen *et al.* (2010). These molecular methods were only used for a qualitative assessment of the presence of

1  
2  
3 155 cryptic species to provide a comprehensive picture of the species diversity attacking *D. kuriphilus*.  
4  
5  
6 156 As resources were not available for molecular identification of every parasitoid specimen all the  
7  
8 157 quantitative analyses of abundance described below were performed at the level of morpho-species  
9  
10 158 rather than genetic species.

12  
13 159 *Abundance patterns in the parasitoid community*

15 160 The number of emerged adults of each parasitoid species was counted and a standardised  
16  
17 161 emergence rate was calculated by dividing the number of emerged adults by the number of galls  
18  
19  
20 162 sampled in that collecting period. Since *D. kuriphilus* galls are multilocular, multiple parasitoids of  
21  
22 163 the same species could emerge from the same gall; our rearing method meant we were unable to  
23  
24  
25 164 determine if this was the case. Hence our emergence rate is not a measure of the exact rate of  
26  
27 165 parasitism, but does provide a method of determining relative parasitoid abundance per unit of  
28  
29 166 sampling effort. Changes over time in the emergence rate of each species in each season were tested  
30  
31  
32 167 for using a logistic regression implemented in SPSS version 17.0. Dates of emergence of the 4 most  
33  
34 168 common parasitoid morpho-species from galls collected in 2009 were plotted to assess whether  
35  
36 169 emergence (and hence parasitism of new hosts) coincided with the development of the next  
37  
38  
39 170 generation of host galls. The secondary sex ratios (i.e. the sex ratio of emerging adults) for each of  
40  
41 171 these 4 species in each season were tested against the null hypothesis of a 50:50 sex ratio, using a  $\chi^2$   
42  
43  
44 172 goodness-of-fit test to examine whether they showed a similar bias to that seen in parasitoids  
45  
46 173 attacking other invading cynipid hosts.

48 174 **Results**

50  
51 175 *Parasitoid species emerging from galls*

53 176 In total 415,224 galls were collected (371,855 withered winter galls and 43,369 newly formed  
54  
55 177 spring galls; Table 1). A total of 10,077 native parasitoid specimens from the superfamily  
56  
57  
58 178 Chalcidoidea emerged across five years. Twenty-three species in six chalcid families (Eurytomidae,  
59  
60 179 Pteromalidae, Torymidae, Eupelmidae, Ormyridae, Eulophidae) were identified using  
180  
morphological characters (Table 2). The molecular analyses revealed the presence of cryptic species

within all of the morpho-species complexes tested, thus adding a further 4 species to the list of parasitoids attacking *D. kuriphilus*. Both cryptic species recognised by Nicholls *et al.* (2010) were found within the *M. dorsalis* morpho-species, although one was sampled at much higher frequency (all but one of the 43 individuals screened). The presence of *E. brunniventris* was confirmed, but some individuals provisionally identified as this species were in fact *Eurytoma adleriae* Zerova. Individuals assigned to the morpho-species *Eupelmus urozonus* were found to be either *E. urozonus* or *E. fulvipes* Förster, and individuals identified morphologically as *Eupelmus annulatus* were either *E. annulatus* or *E. spongipartus* Förster.

Some parasitoid species were found to attack *D. kuriphilus* galls only occasionally, with fewer than ten specimens in total recorded sporadically across the survey period. This was the case for *Aulogymnus arsames* (Walker), *Baryscapus* sp., *Pediobius chilaspidis* Bouček, *P. saulius* (Walker), *Pediobius* sp., *Eupelmus splendens* Giraud, *Ormyrus pomaceus* (Geoffroy), *O. nitidulus* (Fabricius), *Cecidostiba* sp., *Mesopolobus amoenus* (Walker), *M. tarsatus* (Nees), *M. tibialis* (Westwood) and *Torymus flavipes* (Walker). Other species were found more consistently with records from the majority of years, but were only present at low frequency. This set of species included *Sycophila variegata* (Curtis), *S. biguttata* (Swederus), *E. brunniventris*, *Mesopolobus sericeus* (Förster), *Aulogymnus* sp. and *Aprostocetus* sp. (Table S1). Some of these species appeared to be increasing in abundance over time, and often were absent in the early years of sampling, so our data may reflect the initial colonisation of *D. kuriphilus* by these species.

Finally, four species were recorded every year at high frequency: *M. dorsalis*, *E. urozonus*, *E. annulatus* and *Eurytoma pistaciae* Rondani (Table S1). The most frequently collected species was *M. dorsalis*. Overall, this morpho-species accounted for 33.3% of all parasitoid emergences during the study, followed by *E. pistaciae*, *E. annulatus* and *E. urozonus* with 30.1%, 14.1%, and 14.0%, respectively. Three of these species, *M. dorsalis*, *E. annulatus* and *E. pistaciae*, showed significant increases in emergence rate from overwintering galls over the sampling period ( $R^2 = 0.938$ ,  $P = 0.007$ ;  $R^2 = 0.930$ ,  $P = 0.008$ ;  $R^2 = 0.790$ ,  $P = 0.044$  respectively). Neither overwintering *E. urozonus*

nor any species emerging from galls collected in summer showed significant increases in emergence rate over time (Figure 2). All four species showed an emergence pattern consisting of two generations per year (Figure 3). The first generation overwintered in *D. kuriphilus* galls and emerged from the end of April until early June. The second generation resulted from attack of developing galls, with emergence beginning at the end of June and continuing until the end of July or early August (Figure 3). Of these four common parasitoid morphospecies, *M. dorsalis*, *Eupelmus urozonus* and *E. annulatus* showed a general pattern of strongly male-biased sex ratios in their overwintering generations and weakly female-biased ratios in the generations developing within freshly growing *D. kuriphilus* galls (Table 3). The fourth species, *E. pistaciae*, typically showed no bias in sex ratios with the exception of a male bias in the overwintering 2007 generation and a female bias in the summer 2010 generation.

**Discussion**

A total of 27 species in six chalcid families (Eurytomidae, Pteromalidae, Torymidae, Eupelmidae, Ormyridae, Eulophidae) were found to be associated with *D. kuriphilus* galls during the five year period 2006-2010. Seventeen of these species were not recorded by Aebi *et al.* (2006) so represent recent additions to the parasitoid community attacking this pest in Italy, although four of them are cryptic species revealed by molecular analyses so may have been present but simply unrecognised in earlier surveys (for example see Aebi *et al.*, 2007). Aebi *et al.* (2006) recorded five further species associated with *D. kuriphilus* during the early years of the pest's establishment that were not recorded in this study (*Torymus scutellaris* (Walker), *T. auratus* (Müller), *Sycophila iracemae* Nieves-Aldrey, *Mesopolobus mediterraneus* (Mayr) and *Baryscapus pallidae* Graham; Table 2), bringing the total number of parasitoid species known to attack *D. kuriphilus* in Italy to 32. Many of these species appear to parasitise *D. kuriphilus* only occasionally and therefore may be at a very early stage in their recruitment onto this novel host. However, four species (*M. dorsalis*, *E. urozonus*, *E. annulatus* and *E. pistaciae*) are more abundant and appear to have incorporated *D. kuriphilus* into their regular host range.

In its native distribution *D. kuriphilus* populations are kept at low densities by natural enemies; in contrast in regions where it has invaded (Japan, South Korea and the USA) the attack rates of indigenous parasitoid species have remained low many years after the arrival of the pest (typically less than 2%) (Murakami *et al.*, 1995; Ito & Hijii, 2000; Stone *et al.*, 2002; Aebi *et al.*, 2007). This study confirms the same pattern in Italy more than 10 years after *D. kuriphilus* first invaded, despite the species richness of the associated parasitoid community. The emergence rate across all indigenous parasitoids from the summer galls was typically 2-3 individuals per 100 galls, and although the emergence rate from winter galls increased over the study period it still remained relatively low (6 individuals per 100 galls). In addition, since *D. kuriphilus* galls are multilocular, any individual female parasitoid may lay multiple eggs within a single gall so the overall rate of parasitism may well be even lower than our emergence data suggest. As a result, it appears unlikely that current activities of indigenous parasitoids will be able to bring about control of this serious pest. Given the economic and ecological damage caused by *D. kuriphilus* and considering the lack of alternative effective control strategies (EFSA, 2010), this ineffective control by indigenous natural enemies highlights the need for biological control using the exotic parasitoid *T. sinensis* (Quacchia *et al.*, 2008; Gibbs *et al.*, 2011).

The degree to which native parasitoids may help impose some control over *D. kuriphilus* also depends on how well integrated this pest becomes into the oak gall community. The data presented here indicate that although some recruitment of oak gall parasitoids has occurred, there is still a mismatch between the phenology of gall development by the univoltine *D. kuriphilus* and the emergence times of native natural enemies. This pattern is also found for parasitoids that are shared with oak galls in the pest's native China (Murakami *et al.*, 1980). The presence of this phenological mismatch implies that parasitoid exchange between chestnut galls and oak galls is an ongoing process, with occasional use of chestnut galls by a community that has evolved around the use of bivoltine oak galls. However, the extremely high abundance of *D. kuriphilus* galls in its invaded European range represents a massive unexploited resource available for any lineages within

1  
2  
3 259 parasitoid species that have a phenology more suited to that of *D. kuriphilus*. This could provide  
4  
5  
6 260 these lineages with a selective advantage, potentially leading to the development of genetically  
7  
8 261 discrete host-associated ecotypes, one attacking oak galls and the other cycling on chestnut galls.  
9  
10 262 Such a scenario implies that over time the communities centred around the two resources of oak  
11  
12 263 galls and chestnut galls remain relatively distinct, with little exchange of individuals between them.  
13  
14  
15 264 However, genetic data are required to establish whether this may be a possibility or whether  
16  
17 265 parasitoids consider oak- and chestnut-galling cynipids to be ecologically equivalent hosts within a  
18  
19  
20 266 single community.  
21

22 267 Our data provide some preliminary suggestions that *D. kuriphilus* has been integrated into the  
23  
24  
25 268 oak gall community to a sufficient extent that it has impacted upon the behaviour of parasitoids.  
26  
27 269 The observed biases in sex ratios for some parasitoid species suggest that female parasitoids may be  
28  
29 270 altering their laying behaviour in response to the presence of this novel host. However, this remains  
30  
31  
32 271 untested since we did not assess the sex ratios of the corresponding species emerging from native  
33  
34 272 oaks galls, so the observed biases may actually reflect a population-level bias apparent across all  
35  
36 273 hosts. Nevertheless, given its novelty, native parasitoids may view *D. kuriphilus* as a resource of  
37  
38  
39 274 unpredictable or lower quality, and therefore individuals may alter their laying behaviour to take  
40  
41 275 advantage of this novel yet abundant host whilst minimising the risk to overall fitness (Charnov *et*  
42  
43 276 *al.*, 1981). In this case the male-biased sex ratio we observed emerging from overwintering galls  
44  
45  
46 277 may be due to the high relative abundance of chestnut galls in infested areas that act as a sink for  
47  
48 278 excess male eggs that otherwise would not be laid, a phenomenon associated with other invading  
49  
50  
51 279 gallwasp species at high abundance (Hails & Crawley, 1991; Schönrogge *et al.*, 2000).  
52

53 280 Such integration of the invading *D. kuriphilus* into the native oak gall community has broader  
54  
55 281 implications for the evolution of this community. All the parasitoids attacking *D. kuriphilus* have  
56  
57  
58 282 very broad host ranges, a general pattern also seen during the recruitment of parasitoids onto other  
59  
60 283 invading gallwasps (Stone *et al.*, 1995). Our data confirm the presence of some generalist parasitoid  
284 species that were predicted to recruit onto chestnut galls by Aebi *et al.* in 2006, and we could



reasonably expect further generalist species to start attacking *D. kuriphilus* in the near future. In addition, although there is limited evidence for the recruitment of cynipid inquilines onto *D. kuriphilus* galls (Aebi *et al.*, 2006), if these important constituents of the oak gall community were to start utilising chestnut galls we could also expect them to bring along greater parasitoid diversity (Schönrogge *et al.*, 1996) and hence tighten further the trophic links between oak and chestnut gall communities. Given the very large population sizes of *D. kuriphilus* that can act as a significant breeding ground for parasitoids, the presence of these trophic links means there is the potential for severe negative impacts on native oak gall cynipids through the process of apparent competition mediated through shared parasitoid species (Holt, 1977). The larger population sizes that may result from increased use of the abundant *D. kuriphilus* could in turn lead to increased levels of parasitism imposed upon native oak gallers, potentially driving their populations locally extinct (Hassel, 2000) or inducing severe perturbations in the functioning of native communities (Henneman & Memmott, 2001). Such effects may be particularly likely to occur in the oak-chestnut galler community, given that the parasitoid species most frequently attacking *D. kuriphilus* have broad host ranges within native communities (see for example Askew, 1966). In addition, at least one of the commonly encountered species, *E. urozonus*, is known also to attack leaf miners (Askew & Nieves-Aldrey, 2000), so impacts of increased parasitoid attack could extend into the wider community of insects on both chestnuts and oaks.

One further complication is that one of the commonest parasitoids attacking *D. kuriphilus* is *E. urozonus*, a species that can act as a hyperparasitoid and therefore can impose mortality upon multiple trophic levels within a community. A similar phenomenon has recently been observed for the parasitoid *Ormyrus labotus* Walker in the USA (Cooper & Rieske, 2011); in addition to parasitising *D. kuriphilus*, this species also attacks the introduced biological control agent *T. sinensis*. Hence it is imperative that monitoring of the community associated with *D. kuriphilus* continues and that action is taken to minimise the impact this invader has on the wider ecosystem. Furthermore, the potential for apparent competition can be examined in more detail using genetic

1  
2  
3 311 data to assess levels of gene flow among parasitoid populations attacking native oak galls and those  
4  
5 312 attacking chestnut galls. This would allow rates of parasitoid exchange between the different hosts  
6  
7  
8 313 to be assessed, and therefore the degree to which parasitoids from chestnut galls could impact upon  
9  
10 314 native communities.  
11  
12  
13 315 **Acknowledgements**  
14  
15 316 A special thank to Dr R.R. Askew for providing useful comments on the manuscript. This work  
16  
17 317 was supported by a grant of Regione Piemonte.  
18  
19  
20 318 **References**  
21  
22 319 Abe, Y., Melika, G. & Stone, G.N. (2007) The diversity and phylogeography of cynipid gallwasps  
23  
24 320 (Hymenoptera: Cynipidae) of the Oriental and Eastern Palaearctic Regions, and their associated  
25  
26  
27 321 communities. *Oriental Insects*, **41**, 169-212.  
28  
29 322 Aebi, A., Schönrogge, K., Melika, G., Alma, A., Bosio, G., Quacchia, A., Picciau, L., Abe, Y.,  
30  
31 323 Moriya, S., Yara, K., Seljak, G. & Stone, G.N. (2006) Parasitoid recruitment to the globally  
32  
33 324 invasive chestnut gall wasp *Dryocosmus kuriphilus*. *Ecology and evolution of galling arthropods*  
34  
35 325 *and their associates* (ed. by K. Ozaki, J. Yukwa, T. Ohgushi, P.W. Price), pp. 103-121, Springer-  
36  
37 326 Verlag, Tokyo, Japan.  
38  
39 327 Aebi, A., Schönrogge, K., Melika, G., Quacchia, A., Alma, A. & Stone, G.N. (2007) Native and  
40  
41 328 introduced parasitoids attacking the invasive chestnut gall wasp *Dryocosmus kuriphilus*. *EPPO*  
42  
43 329 *Bulletin*, **37**, 166-171.  
44  
45  
46 330 Askew, R.R. (1966) Observations on the British species of *Megastigmus* Dalman (Hym.  
47  
48 331 Torymidae) which inhabit cynipid oak galls. *Entomologist* **99**, 124-128.  
49  
50  
51 332 Askew, R.R. & Nieves-Aldrey, J.L. (2000) The genus *Eupelmus* Dalman, 1820 (Hymenoptera,  
52  
53 333 Chalcidoidea, Eupelmidae) in peninsular Spain and the Canary Islands, with taxonomic notes and  
54  
55 334 descriptions of new species. *Graellsia*, **56**, 49-61.  
56  
57  
58  
59  
60



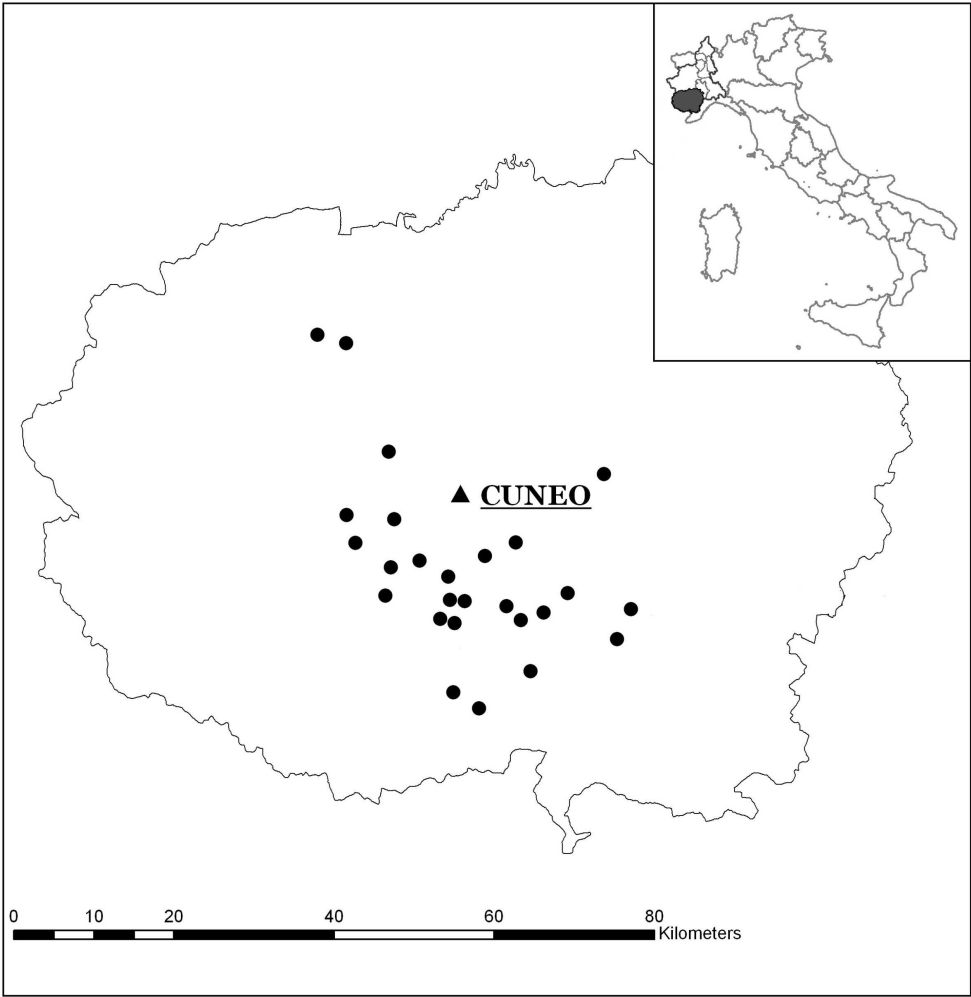
- 335 Bouček, Z. (1970) Contribution to the knowledge of Italian Chalcidoidea, based mainly on a study  
 336 at the Institute of Entomology in Turin, with descriptions of some new European species. *Estratto*  
 337 *dalle Memorie della Società Entomologica Italiana*, **49**, 35-102.
- 338 Brussino, G., Bosio, G., Baudino, M., Giordano, R., Ramello, F. & Melika, G. (2002) Pericoloso  
 339 insetto esotico per il castagno europeo. *L'Informatore Agrario*, **37**, 59-61.
- 340 Charnov, E.L., Los-den Hartogh, R.L., Jones, W.T., & van den Assem, J. (1981) Sex ratio evolution  
 341 in a variable environment. *Nature*, **289**, 27-33.
- 342 Cooper, W.R. & Rieske, L.K. (2007) Community associates of an exotic gallmaker, *Dryocosmus*  
 343 *kuriphilus* (Hymenoptera: Cynipidae), in Eastern North America. *Annals of the Entomological*  
 344 *Society of America*, **100**, 236-244.
- 345 Cooper, W.R. & Rieske, L.K. (2011) A native and an introduced parasitoid utilize an exotic  
 346 gall-maker host. *BioControl*, **56**, 725-734.
- 347 EFSA Panel on Plant Health (PLH) (2010) Risk assessment of the oriental chestnut gall wasp,  
 348 *Dryocosmus kuriphilus* for the EU territory 443 on request from the European Commission. *EFSA*  
 349 *Journal*, **8**, 1619.
- 350 EPPO (2005) Data sheets on quarantine pests - *Dryocosmus kuriphilus*. *EPPO Bulletin*, **35**, 422-  
 351 424.
- 352 Gibbs, M., Schönrogge, K., Alma, A., Melika, G., Quacchia, A., Stone, G.N., Aebi, A. (2011)  
 353 *Torymus sinensis*: a viable management option for the biological control of *Dryocosmus*  
 354 *kuriphilus* in Europe? *BioControl*, **56**, 527-538.
- 355 Gibson, A.P. (2011) The species of *Eupelmus* (*Eupelmus*) Dalman and *Eupelmus* (*Episolindelia*)  
 356 Girault (Hymenoptera: Eupelmidae) in North America north of Mexico. *Zootaxa*, **2951**, 1-97.
- 357 Hails, R.S. (1989) Host size and sex allocation of parasitoids in a gall forming community.  
 358 *Oecologia*, **81**, 28-32.
- 359 Hails, R.S. & Crawley, M.J. (1991) The population dynamics of an alien insect: *Andricus*  
 360 *quercuscalicis* (Hymenoptera: Cynipidae). *Journal of Animal Ecology*, **60**, 545-562.

- 1  
2  
3 361 Hassel, M.P. (2000) Host-parasitoid population dynamics. *Journal of Animal Ecology*, **69**, 543-566.  
4  
5  
6 362 Henneman, M.L. & Memmott, J. (2001) Infiltration of a Hawaiian community by introduced  
7  
8 363 biological control agents. *Science*, **293**, 1314-1316.  
9  
10 364 Holt, R.D. (1977) Predation, apparent competition, and the structure of prey communities.  
11  
12 365 *Theoretical Population Biology*, **12**, 197-229.  
13  
14  
15 366 IPLA (2004) Regione Piemonte. *Collana Manuali Tecnico-divulgativi di Selvicoltura*. Tipi forestali  
16  
17 367 del Piemonte. Blu Edizioni, Torino, Italy.  
18  
19  
20 368 Ito, M. & Hijii, N. (2000) Life-history traits in the parasitoid complex associated with cynipid galls  
21  
22 369 on three species of Fagaceae. *Entomological Science*, **3**, 471-479.  
23  
24  
25 370 Kamijo, K. (1981) Pteromalid wasps (Hymenoptera) reared from cynipid galls on oak and chestnut  
26  
27 371 in Japan, with descriptions of four new species. *Kontyû*, **49**, 272-282.  
28  
29 372 Kamijo, K. (1982) Two new species of *Torymus* (Hymenoptera, Torymidae) reared from  
30  
31 373 *Dryocosmus kuriphilus* (Hymenoptera, Cynipidae) in China and Korea. *Kontyû*, **50**, 505-510.  
32  
33  
34 374 Kaartinen, R., Stone, G.N., Hearn, J., Lohse, K. & Roslin, T. (2010) Revealing secret liaisons: DNA  
35  
36 375 barcoding changes our understanding of food webs. *Ecological Entomology*, **35**, 623-638.  
37  
38  
39 376 Kim, J.K. (1998) Studies on the parasitoids of chestnut gall wasp, *Dryocosmus kuriphilus*  
40  
41 377 Yasumatsu (Hymenoptera: Cynipidae) in Korea. *Journal of Korean Forestry Society*, **87**, 475-482.  
42  
43 378 Ko, J.H. (1971) Notes on *Eudecatoma variegata* Curtis (Hymenoptera: Eurytomidae) as a parasite  
44  
45 379 of the gall wasps (Cynipidae) in Korea. *The Korean Journal of Entomology*, **1**, 25-26.  
46  
47  
48 380 Luo, Y.Q. & Huang, J.F. (1993) A preliminary morphological study on immature stage of natural  
49  
50 381 enemies of *Dryocosmus kuriphilus* Yasumatsu (in Chinese). *Scientia Silvae Sinicae* (Linze Kexue),  
51  
52 382 **29**, 33-39.  
53  
54  
55 383 Moriya, S., Inoue, K. & Mabuchi, M. (1990) Use of *Torymus sinensis* (Hymenoptera, Torymidae)  
56  
57 384 for controlling the chestnut gall wasp, *Dryocosmus kuriphilus* (Hymenoptera, Cynipidae), in Japan.  
58  
59  
60 385 FFTC-NARC International Seminar on 'The use of parasitoids and predators to control agricultural  
386 pests', Tukuba Science City, Ibaraki-ken, 305 Japan, October 2-7, 1989. pp. 21.

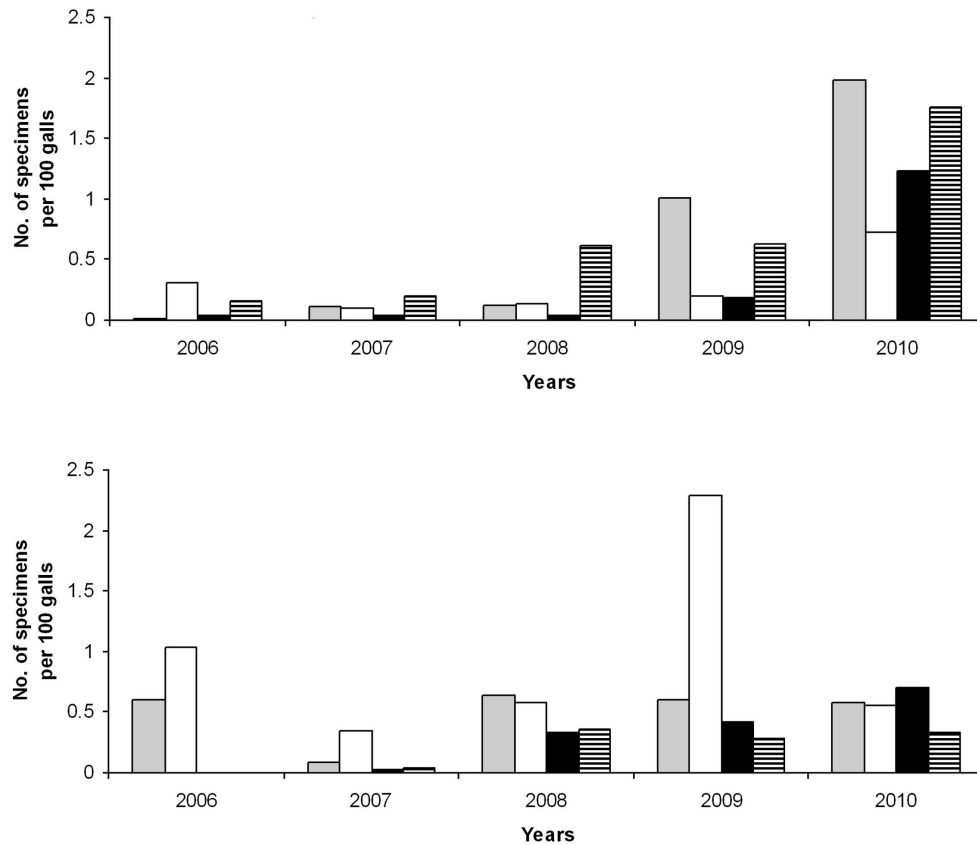
- Murakami, Y. (1981) Comparison of the adult emergence periods between *Torymus* (*Syntomaspis*) *beneficus* a native parasitoid of the chestnut gall wasp and a congeneric parasitoid imported from China (Hymenoptera: Torymidae) (in Japanese). *Proceedings of the Association for Plant Protection of Kyushu*, **27**, 156-158.
- Murakami, Y., Ao, H.B. & Chang, C.H. (1980) Natural enemies of the chestnut gall wasp in Hopei Province, China (Hymenoptera: Chalcidoidea). *Applied Entomology and Zoology*, **15**, 184-186.
- Murakami, Y., Hiramatsu, T. & Maeda, M. (1994) Parasitoid complexes of the chestnut gall wasp (Hymenoptera: Cynipidae) in two localities before introduction of *Torymus* (*Syntomaspis*) *sinensis* (Hymenoptera: Torymidae) with special reference to prediction of results after release of the parasitoid (in Japanese). *Japanese Journal of Applied Entomology and Zoology*, **38**, 29-41.
- Murakami, Y., Ohkubo, N., Moriya, S., Gyoutoku, Y., Kim, C.H. & Kim, J.K. (1995) Parasitoids of *Dryocosmus kuriphilus* (Hymenoptera: Cynipidae) in South Korea with particular reference to ecologically different types of *Torymus* (*Syntomaspis*) *sinensis* (Hymenoptera: Torymidae). *Applied Entomology and Zoology*, **30**, 277-284.
- Murakami, Y., Uemura, M. & Gyoutoku, Y. (1985) Colonization of imported *Torymus* (*Syntomaspis*) *sinensis* Kamijo (Hymenoptera: Torymidae) parasitic on the chestnut gall wasp (Hymenoptera: Cynipidae). (2) Recovery in Kumamoto Prefecture (in Japanese). *Proceedings of the Association for Plant Protection of Kyushu*, **31**, 216-219.
- Nicholls, J.A., Preuss, S., Hayward, A., Melika, G., Csóka, G., Nieves-Aldrey, J.L., Askew, R.R., Tavakoli, M., Schönrogge, K. & Stone, G.N. (2010) Concordant phylogeography and cryptic speciation in two Western Palearctic oak gall parasitoid species complexes. *Molecular Ecology*, **19**, 592-609.
- Ôtake, A. (1989) Chestnut gall wasp *Dryocosmus kuriphilus* Yasumatsu (Hymenoptera: Cynipidae) analysis of records of cell contents inside galls and on emergence of wasps and parasitoids outside galls. *Applied Entomology and Zoology*, **24**, 193-201.

- Ôtake, A., Shiga, M. & Moriya, S. (1982) A study on parasitism of the chestnut gall wasp, *Dryocosmus kuriphilus* Yasumatsu (Hymenoptera: Cynipidae) by parasitoids indigenous to Japan. *Bulletin of the Fruit Tree Research Station*, **9**, 177-192.
- Payne, J.A., Jaynes, R.A. & Kays, S.J. (1983) Chinese chestnut production in the United States: practice, problems and possible solutions. *Economic Botany*, **37**, 187-200.
- Parker, I.M., Simberloff, D., Lonsdale, W.M., Goodell, K., Wonham, M., Kareiva, P.M., Williamson, M.H., Von Holle, B., Moyle, P.B., Byers, J.E., Goldwasser, L. (1999) Impact: toward a framework for understanding the ecological effects of invaders. *Biological Invasions*, **1**, 3-19.
- Quacchia, A., Moriya, S., Bosio, G., Scapin, G. & Alma, A. (2008) Rearing, release and settlement prospect in Italy of *Torymus sinensis*, the biological control agent of the chestnut gall wasp *Dryocosmus kuriphilus*. *BioControl*, **53**, 829-839.
- Reitz, S.R. & Trumble, J.T. (2002) Competitive displacement among insects and arachnids. *Annual Review of Entomology*, **47**, 435-465.
- Rieske, L.K. (2007) Success of an exotic gallmaker, *Dryocosmus kuriphilus*, on chestnut in the USA: a historical account. *OEPP/EPPO Bulletin*, **37**, 172-174.
- Schönrogge, K., Stone, G.N. & Crawley, M.J. (1996) Alien herbivores and native parasitoids: rapid developments and structure of the parasitoid and inquiline complex in an invading gall wasp *Andricus quercuscalicis* (Hymenoptera: Cynipidae). *Ecological Entomology*, **21**, 71-80.
- Schönrogge, K., Walker, P. & Crawley, M.J. (2000) Parasitoid and inquiline attack in the galls of four alien, cynipid gall wasps: host switches and the effect on parasitoid sex ratios. *Ecological Entomology*, **25**, 208-219.
- Stone, G.N., Schönrogge, K., Crawley, M.J. & Fraser, S. (1995) Geographic and between-generation variation in the parasitoid communities associated with an invading gallwasp, *Andricus quercuscalicis* (Hymenoptera: Cynipidae). *Oecologia*, **104**, 207-217.

- van Lenteren, J.C., Bale, J., Bigler, E., Hokkanen, H.M.T., Loomans, A.M. (2006) Assessing risks of releasing exotic biological control agents of arthropod pests. *Annual Review of Entomology*, **51**, 609-634.
- Vitousek, P.M., D'Antonio, C.M., Loope, L.L. & Westbrooks, R. (1996) Biological invasion as global environmental change. *American Scientist*, **84**, 468-478.
- Williamson, M. (1996) *Biological invasions*. Chapman and Hall, London, UK.
- Wilson, E.O. (1997) Foreword. *Strangers in paradise: impact and management of nonindigenous species in Florida* (ed. by D. Simberloff, D.C. Schmitz and T.C. Brown). 453 pp., Island Press, Washington DC, USA.
- Wittenberg, R. & Cock, M.J.W. (2001) *Invasive alien species: a toolkit of best prevention and management practices*. CAB International, Wallingford, Oxon, UK.
- Yasumatsu, K. & Kamijo, K. (1979) Chalcidoid parasites of *Dryocosmus kuriphilus* Yasumatsu (Cynipidae) in Japan, with descriptions of five new species (Hymenoptera). *Esakia*, **14**, 93-111.

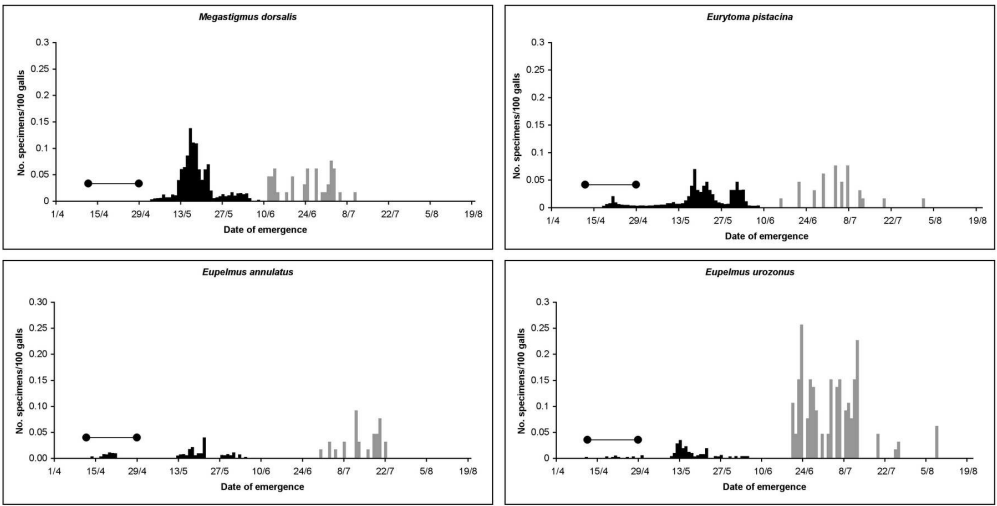


Location of the 26 sampling sites in Cuneo province, with inset showing the location of Cuneo province within Italy.  
204x209mm (300 x 300 DPI)



Emergence rates of the four most common parasitoid species attacking *Dryocosmus kuriphilus* galls in Cuneo province, Italy, over the years 2006-2010. The upper graph shows winter emergence, the lower one shows summer emergence. Shading of bars indicates species: grey *Megastigmus dorsalis*, white *Eupelmus urozonus*, black *Eupelmus annulatus*, stripes *Eurytoma pistaciae*.

196x183mm (300 x 300 DPI)



Seasonal patterns of emergence of the four most common parasitoid species attacking *Dryocosmus kuriphilus* galls in Cuneo province, Italy, in 2009. Black bars show emergence from withered galls collected in winter 2008-2009, grey bars show emergence from newly formed galls collected in summer 2009; the line indicates the growth period of *D. kuriphilus* galls.

152x78mm (300 x 300 DPI)



Province, Italy.

[illegible]

1  
2  
3  
4  
5  
6  
7  
8  
9  
10  
11  
12  
13  
14  
15  
16  
17  
18  
19  
20  
21  
22  
23  
24  
25  
26  
27  
28  
29  
30  
31  
32  
33  
34  
35  
36  
37  
38  
39  
40  
41  
42  
43  
44  
45  
46  
47  
48  
49  
50  
51  
52  
53  
54  
55  
56  
57  
58  
59  
60

Table 2. Parasitoid species attacking the chestnut gallwasp *Dryocosmus kuriphilus* in north-western Italy. Species names in bold indicate cryptic species pairs which molecular data resolve; not all individuals collected each year from these species pairs were sequenced, so the presence of the first mentioned species indicates presence of the corresponding morpho-species. Data for the years 2002-2005 are from Aebi *et al.*, 2006.

Species	Family	2002-2005	2006	2007	2008	2009	2010
<i>Aprostocetus</i> sp.	Eulophidae		X	X	X	X	X
<i>Aulogymnus arsames</i>	Eulophidae					X	
<i>Aulogymnus</i> sp.	Eulophidae			X	X	X	X
<i>Baryscapus pallidae</i>	Eulophidae	X					
<i>Baryscapus</i> sp.	Eulophidae						X
<i>Pediobius chilaspidis</i>	Eulophidae			X			
<i>Pediobius saulius</i>	Eulophidae				X		X
<i>Pediobius</i> sp.	Eulophidae			X	X		X
<b><i>Eupelmus annulatus</i>*</b>	Eupelmidae		X	X	X	X	X
<b><i>Eupelmus spongipartus</i>*</b>	Eupelmidae					X	
<i>Eupelmus splendens</i>	Eupelmidae			X		X	
<b><i>Eupelmus urozonus</i></b>	Eupelmidae	X	X	X	X	X	X
<b><i>Eupelmus fulvipes</i></b>	Eupelmidae					X	
<b><i>Eurytoma brunniventris</i></b>	Eurytomidae	X		X	X	X	X
<b><i>Eurytoma adleriae</i></b>	Eurytomidae						X
<i>Eurytoma pistaciae</i>	Eurytomidae	X	X	X	X	X	X
<i>Sycophila variegata</i>	Eurytomidae	X	X	X	X	X	X
<i>Sycophila biguttata</i>	Eurytomidae	X		X		X	X
<i>Sycophila iracemae</i>	Eurytomidae	X					
<i>Ormyrus nitidulus</i>	Ormyridae					X	
<i>Ormyrus pomaceus</i>	Ormyridae	X				X	X
<i>Cecidostiba</i> sp.	Pteromalidae				X		X
<i>Mesopolobus amaenus</i>	Pteromalidae				X		
<i>Mesopolobus mediterraneus</i>	Pteromalidae	X					
<i>Mesopolobus sericeus</i>	Pteromalidae	X		X	X	X	X
<i>Mesopolobus tarsatus</i>	Pteromalidae	X		X		X	
<i>Mesopolobus tibialis</i>	Pteromalidae			X			
<b><i>Megastigmus dorsalis</i> (sp1)</b>	Torymidae	X	X	X	X	X	X
<b><i>Megastigmus dorsalis</i> (sp2)</b>	Torymidae					X	
<i>Torymus auratus</i>	Torymidae	X					
<i>Torymus flavipes</i>	Torymidae	X		X			
<i>Torymus scutellaris</i>	Torymidae	X					

\*Bouček's (1970) consideration of *Eupelmus annulatus* and *E. spongipartus* as synonyms appears to be incorrect and the names do represent two distinct species (Gibson, 2011).

Table 3. Number of females and males of the four most abundant parasitoid species emerging from *Dryocosmus kuriphilus* galls in north-western Italy in the period 2006-2010. The observed sex ratios were tested against an expected 50:50 ratio (all d.f. = 1, \*P<0.05, \*\*P<0.01, \*\*\*P<0.001; NS=not significant).

2006						
	winter			summer		
	F	M	$\chi^2$	F	M	$\chi^2$
<i>Megastigmus dorsalis</i>	0	1	NS	22	2	16.67***
<i>Eupelmus urozonus</i>	12	16	NS	38	3	29.88***
<i>Eupelmus annulatus</i>	3	0	NS	-	-	-
<i>Eurytoma pistaciae</i>	6	8	NS	-	-	-
2007						
	winter			summer		
	F	M	$\chi^2$	F	M	$\chi^2$
<i>Megastigmus dorsalis</i>	14	60	28.59***	8	12	NS
<i>Eupelmus urozonus</i>	20	45	9.62**	46	38	NS
<i>Eupelmus annulatus</i>	18	3	10.71**	4	2	NS
<i>Eurytoma pistaciae</i>	32	93	29.77***	2	8	NS
2008						
	winter			summer		
	F	M	$\chi^2$	F	M	$\chi^2$
<i>Megastigmus dorsalis</i>	11	86	57.99***	20	9	4.17*
<i>Eupelmus urozonus</i>	29	82	25.31***	15	11	NS
<i>Eupelmus annulatus</i>	10	19	NS	9	6	NS
<i>Eurytoma pistaciae</i>	241	245	NS	11	5	NS
2009						
	winter			summer		
	F	M	$\chi^2$	F	M	$\chi^2$
<i>Megastigmus dorsalis</i>	227	1115	587.59***	28	12	6.40*
<i>Eupelmus urozonus</i>	78	177	38.44***	96	57	9.94**
<i>Eupelmus annulatus</i>	77	165	32.00***	25	3	17.29***
<i>Eurytoma pistaciae</i>	391	446	NS	13	6	NS
2010						
	winter			summer		
	F	M	$\chi^2$	F	M	$\chi^2$
<i>Megastigmus dorsalis</i>	401	1300	475.13***	15	9	NS
<i>Eupelmus urozonus</i>	446	180	113.03***	17	6	5.26*
<i>Eupelmus annulatus</i>	400	652	60.37***	21	8	5.83*
<i>Eurytoma pistaciae</i>	757	754	NS	12	2	7.14**

Table S1. Emergence data for the 10 parasitoid species found to attack *Dryocosmus kuriphilus* galls regularly in north-western Italy during the period 2006-2010. Both the total number of specimens (ns) and the standardised emergence rate (er; number of adults emerging per 100 galls) are presented.

	2006				2007				2008				2009				2010			
	winter		summer		winter		summer		winter		summer		winter		summer		winter		summer	
	ns	er	ns	er	ns	er	ns	er	ns	er	ns	er	ns	er	ns	er	ns	er	ns	er
<i>Megastigmus dorsalis</i>	1	0.01	24	0.61	74	0.11	20	0.08	97	0.12	29	0.64	1342	1.01	40	0.60	1701	1.98	24	0.58
<i>Eurytoma pistaciae</i>	14	0.16	-	-	125	0.19	10	0.04	486	0.61	16	0.36	837	0.63	19	0.28	1511	1.76	14	0.34
<i>Eupelmus annulatus</i>	3	0.03	-	-	21	0.03	6	0.02	29	0.04	15	0.33	242	0.18	28	0.42	1052	1.23	29	0.70
<i>Eupelmus urozonus</i>	28	0.31	41	1.04	65	0.10	84	0.35	111	0.14	26	0.58	255	0.19	153	2.29	626	0.73	23	0.55
<i>Sycophila variegata</i>	-	-	6	0.15	1	0.00	-	-	4	0.01	3	0.07	18	0.01	2	0.03	74	0.09	5	0.12
<i>Sycophila biguttata</i>	-	-	3	0.08	-	-	6	0.02	-	-	2	0.04	3	0.00	1	0.01	33	0.04	-	-
<i>Eurytoma brunniventris</i>	-	-	-	-	-	-	50	0.21	1	0.00	9	0.20	10	0.01	-	-	1	0.00	-	-
<i>Mesopolobus sericeus</i>	-	-	-	-	2	0.00	-	-	19	0.02	-	-	10	0.01	-	-	161	0.19	15	0.36
<i>Aulogymnus</i> sp.	-	-	-	-	31	0.05	-	-	21	0.03	-	-	26	0.02	-	-	16	0.02	-	-
<i>Aprostocetus</i> sp.	-	-	23	0.58	47	0.07	-	-	1	0.00	-	-	5	0.00	-	-	16	0.02	-	-
total	92	0.51	97	2.45	366	0.56	176	0.73	769	0.97	100	2.22	2748	2.08	243	3.64	5191	6.05	110	2.65